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Os-He isotope systematics of Iceland picrites: Evidence for a deep origin of the Iceland plume

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Recent work on the origin of the Iceland hotspot suggests that it may result from upwelling upper mantle material rather than a deep plume. To constrain the depths of origins of Iceland mantle sources, Os and He isotope systematics were obtained on a suite picrites that span the compositional range observed within the neovolcanic zones.

The Iceland picrites display a range in $^{187}Os/^{188}Os$ from 0.1297 to 0.1381 (g_{Os} = 0.0 to 6.5) and uniform $^{186}Os/^{188}Os$ of 0.1198375±32 (2s). The value for $^{186}Os/^{188}Os$ is within uncertainty of the present-day value for the primitive upper mantle of 0.1198398±16. These Os isotope systematics are best explained by ancient recycled crust or melt enrichment in the mantle source region. If so, then the coupled enrichments displayed in $^{186}Os/^{188}Os$ and $^{187}Os/^{188}Os$ from lavas of other plume systems must result from an independent process, the most viable candidate at present remains core-mantle interaction. While some plumes with high $^{3}He/^{4}He$, such as Hawaii, appear to have been subjected to detectable addition of Os (and possibly He) from the outer core, others such as Iceland, appear to have not.

A positive correlation between $^{187}Os/^{188}Os$ from 0.1297 to 0.1381 and $^{3}He/^{4}He$ from 9.6 to 19 R_A in Iceland picrites is best modeled as a two stage process. In stage 1, 500 Ma or older ancient recycled crust is mixed with a primitive-like mantle for Os and He systematics, creating a hybrid source region. In stage 2, the hybrid source mixes with the convecting MORB mantle during ascent and melting. This multistage mechanism to explain these isotope systematics is consistent with ancient recycled crust juxtaposed with more primitive, relatively He-rich mantle, in convective isolation from the upper mantle, most likely in the lowermost mantle. This is inconsistent with models that propose random mixing between heterogeneities in the convecting upper mantle as a mechanism to explain the observed isotopic variation in oceanic lavas or models that produce a high $^{3}He/^{4}He$ signature in melt depleted and strongly outgassed, He-poor mantle. Instead these systematics require a deep mantle source to explain the $^{3}He/^{4}He$ signature in Iceland lavas.

The lack of a resolvable seismic signature of conduit-like plume flow under Iceland at some depths may result from sporadic flow of material from depths near the core-mantle boundary, consistent with recent dynamical models (Farnetani and Samuel, 2005, GRL 32, L07311).